Harvesting systems for multiple products An update for the United States

Dr. Bryce J. Stokes
USDA Forest Service
Southern Forest Research Station
Auburn University, Alabama 36949, USA

1 Introduction

As expected, currently and for years to come, the demand for energy will increase, especially for transportation. Other increases will be for natural gas for residential and industrial use, and for renewables as a response to environmental awareness. However, for the short term, economics dictate energy source selection and use; bioenergy has not been competitive. There are the extraneous factors such as environmental constraints and reduction of subsidies in the Conservation Reserve Program that might accelerate the use of biomass for energy. There may come more incentives to change to bioenergy.

The deregulation of the electric power industry is forcing the industry to become more competitive (DOE/IEA 1997). Congress is considering repealing or extensively modifying laws that would strengthen the relative position of large utilities and large, well-capitalized nonutility generators, and it would potentially weaken the position of the renewable energy industry. Proposed responses include the promotion of continued commercialization of renewable energy technologies by specifying minimum levels of renewable-generated electricity at the State level. In addition, electric utilities are using a voluntary approach, the use of "green pricing" programs, as a way to promote the use of renewable energy.

As far as forestry, there is much potential for furnishing bioenergy, but very little application (Bioenergy 1996). As an example, bioenergy use in the South is 1.6 quads, which is 56 percent of Nation's use. This is still a very insignificant amount; only 6 percent of energy consumption in the South was wood, and wood was only used to produce about 2.4 percent of the electricity. This clearly does not align with potential for bioenergy production. By using residues and using forestry and agricultural energy products, the bioenergy potential is 4 to 7 quads.

Useful Energy Conversion Factors:

1 Btu = 1.055.056 joules(J)
1 quad = 1 quadrillion Btu of energy
= 1 x 10^{15} Btu of energy
= 40.82 million metric tons of coal
= 54.43 million metric tons of oven-dried hardwood
= 27.1 cubic meters of crude oil

The range of utility of woody biomass is very wide across the Nation, and varies because of many factors. The forest industry is probably the largest user as well as the largest generator of woody biomass. Pulp and paper mills, which are high users of woody biomass in co-generation, also can produce excess wood residues that are even a disposal problem. Only a few buy market residues and have procurement systems to obtain the needed boiler fuels.

2 Use of biomass

The Nation's total energy supply provided by biomass (predominately wood, but includes wastes and alcohol fuels) has been increasing for the past 5 years; currently up to 3.0 quadrillion Btu (Table 1). Of the total 1996 energy consumption of 93.8 quads, biomass was only 3.2 percent of the source. Biomass energy consumption was 41 percent of the total renewable energy sources. When excluding hydropower, a renewable energy resource that is considered as "conventional," biomass accounted for 87 percent of the remaining renewable energy consumption in 1996. Wood pellets is a fast-growing biomass fuel market. In the residential and commercial sectors, an increase in residential wood use for heating resulted in a 10-percent increase in renewable energy consumption in 1995. U.S. pellet fuel production increased by 18 percent between the 1993—94 and 1995—96 heating seasons (DOE/IEA 1996).

In 1996, the residential/commercial sector used biomass for 90.8 percent of the renewable energy consumed; almost all was wood for heating (Table 2). Almost 84 percent of the renewables used in the industrial sector was biomass. A substantial amount was probably used for generating heat instead of electricity. Very little biomass was used to generate electricity in the electric utility.

Renewable electricity generation rose to 465 billion kilowatt-hours in 1996 (Table 3). Biomass accounted for almost 14 percent of the source of the generation; almost 97 percent within the industrial sector. Biomass was used very little in the electrical utility sector, although there was a slight increase from 1995 when it had made a significant decrease.

Table 1. U.S. Renewable energy consumption by Source, 1992—1996 (Quadrillion Btu).

Energy Source	1992	1993	1994	1995	1996
Conventional hydroelectric power[a]	2.852	3.138	2.958	R3.471	3.911
Geothermal energy	0.367	0.381	0.381	0.325	0.354
Biomass[b]	2.788	2.784	R2.838	R2.946	3.017
Solar energy[c]	0.068	R0.071	R0.072	0.073	0.075
Wind energy	0.030	0.031	0.036	0.033	0.036
Total renewable energy	6.106	R6.404	R6.285	R6.847	7.393

[a] Hydroelectricity generated by pumped storage is not included in renewable energy.
[b] Includes wood, wood waste, peat, wood sludge, municipal solid waste, agricultural waste, straw, tires, landfill gases, fish oils, and/or other waste.
[c] Includes solar thermal and photovoltaic.
R = Revised data.
Sources: 1992—1996: Energy Information Administration (EIA), Annual Energy Review 1996, DOE/EIA-0384(96) (Washington, DC, July 1997).

Table 2. Renewable energy consumption by Sector and Energy Source, 1992—1996 (Quadrillion Btu).

Sector and Source	1992	1993	1994	1995	1996
Residential/Commercial					
Biomass	0.645	0.592	0.582	0.651	0.644
Solar	0.060	R0.062	R0.064	R0.065	0.066
Total	0.705	R0.654	R0.646	R0.706	0.709
Industrial[a]					
Biomass	2.042	2.084	R2.138	R2.184	2.279
Geothermal	0.179	0.204	0.212	0.207	0.231
Conventional hydroelectric[b]	0.097	0.118	0.136	0.152	0.172
Solar	0.008	0.009	0.008	0.008	0.009
Wind	0.030	0.031	0.036	0.033	0.036
Total	2.357	2.446	R2.530	R2.584	2.727
Transportation					
Biomass[c]	0.079	0.088	R0.097	R0.104	0.074
Electric Utility					
Biomass	0.022	0.020	0.020	0.017	0.020
Geothermal	0.169	0.158	0.145	0.099	0.110
Conventional hydroelectric[b]	2.511	2.766	R2.583	R3.053	3.419
Solar and wind	*	*	*	*	*
Net renewable energy imports[d]	0.263	0.271	0.309	R0.284	0.333
Total	2.065	3.217	R3.012	R3.453	3.883
Total renewable energy Consumption	6.106	R6.404	R6.285	R6.847	7.393

*Less than 0.5 trillion Btu. R = revised data.
[a] Includes generation of electricity by cogenerators, independent power producers, and small power producers.
[b] Hydroelectricity generated by pumped storage is not included in renewable energy.
[c] Ethanol blended into gasoline.
[d] Includes only net imports of electricity known to be from renewable resources (geothermal and hydroelectric).
Sources: See Table 1.

3 Harvest system

The most prevalent harvest system in the South is the tree-length system. Highly productive feller-bunchers are used to fell, collect, and bunch many small stems into piles. The trees are delimbed and topped in the woods either using a chainsaw or delimbing gate with chainsaws at the deck. Grapple skidders are used to extract the trees and the stems are usually loaded tree-length onto trailers. Improvements have been the addition of mechanical processors and slashers. The limbs and tops are left at the processing area, or carried back onto the stand by the skidder. Some feller-buncher/ skidder systems use a flail delimber/debarker and a chipper to produce clean chips at the deck (Stokes & Watson 1988 and 1996). Flail processing and chipping is potentially more economical for small diameter trees than delimbing and hauling tree-length wood. Another advantage is the potential biomass recovery. The limbs, tops, and bark can be hogged at the deck and used as fuel. Cut-to-length (CTL) systems are becoming more widely used. Harvesters are used for felling and processing at the stump.

Table 3. Electricity generation from renewable energy by Energy Source, 1992—1996 (MWh).

Source	1992	1993	1994	1995	1996
Industrial Sector[a]					
Biomass	R53 606	R55 745	R57 391	56 975	62 107
Geotherm	R8 577	R9 748	R10 122	9 911	11 014
Hydroelectric	R9 446	R11 510	R13 226	14 773	16 711
Solar	R746	R896	R823	824	908
Wind	R2 916	R3 052	R3 481	3 185	3 507
Total	R75 293	80 954	85 046	R85 669	94 249
Electric Utility Sector (Net Generation)[b]					
Biomass	2 092	1 990	1 988	1 649	1 967
Geothermal	8 103	7 570	6 940	4 744	5 233
Conventional Hydroelectric	243 736	269 098	247 070	R296 377	331 035
Solar	3	4	3	4	3
Wind	*	*	*	11	10
Total	253 936	278 663	256 003	R302 786	339 149
Net Imports	24 583	25 496	28 844	26 648	31 673
Total Renewable Generation	R353 814	R385 114	R369 894	R415 105	465 072

* Less than 500 MWh

[a] Includes cogenerators, independent power producers, and small power producers.

[b] Excludes imports.

R = Revised data.

Sources: Energy Information Administration, Form EIA-759, "Monthly Power Plant Report"; From EIA-867, "Annual Nonutility Power Producer Report"; and Electric Power Monthly March 1997, DOE/EIA-0226(75/03) Washington, DC, March 1997).

Table 4. Stands used for harvesting cost analysis.

Stand	Initial			Harvested				
	DBH	TPH	BA/HA	DBH	TPH	BA/HA	Whole (Tonnes/HA)	Merchantable (Tonnes/HA)
Thinning, 13—15 yrs	18.3	684	19	16.0	319	7	48.4	34.5
Thinning, 16—18 yrs	19.3	689	21	17.3	306	8	55.4	39.7
Clearcut, 23 yrs	20.6	650	23	20.6	650	23	178.7	137.6

Note: DBH is diameter at breast height in centimeters; TPH is trees per hectare; BA/HA is basal area in m^2 per hectare; Whole is harvested whole tree weight including wood, bark, limbs, tops and foliage in tonnes per hectare; Merchantable is harvested merchantable weight in tonnes per hectare to a 10 centimeter top.

4 Stand descriptions

Three loblolly (*Pinus taeda*) stands were selected as typical pine plantations to analyze the productivity and cost of the three selected systems. Table 4 summarizes the composition of the representative stands used for a range of structure and removal levels. The stand information was only for pine trees 13 cm, DBH, and larger; these were considered merchantable. The 13—15 year old stand, as an early thinning, had an initial basal area of 19 m^2/ha and a removal of 7 m^2/ha. The 16—18 year old stand was considered to be a late thinning and had an initial basal area of 21 m^2/ha. A total of 8 m^2/ha were removed. In the thinnings, every fifth row was harvested and the rest were removed by selection. The clearcut stand had 23 m^2/ha harvested. Merchantable tonnes per hectare were calculated to a 10-cm top.

5 Utilization

A study was conducted at a local pulpmill in Alabama to estimate the recovery and utilization for the three representative stands. Five tree-length truck loads of loblolly plantation pine were processed through a tree-length (longwood) drum debarker to determine merchantable chip recovery. Additional laboratory work was completed to determine chip quality and size distribution. The same procedure was used to determine the recovery of cut-to-length wood. Four loads of random length wood were processed on the same longwood yard as the tree-length wood was processed. One load of the CTL wood was processed at a shortwood drum, after being slashed into 1.5-m lengths.

The authors have completed several studies on the recovery of loblolly pine plantation wood using a flail delimber/debarker and chipper (Flowers et al. 1992, Stokes & Watson 1988 and 1994, Watson et al. 1992). This published information concerning the recovery of products from a flail/chipper was used in this analysis.

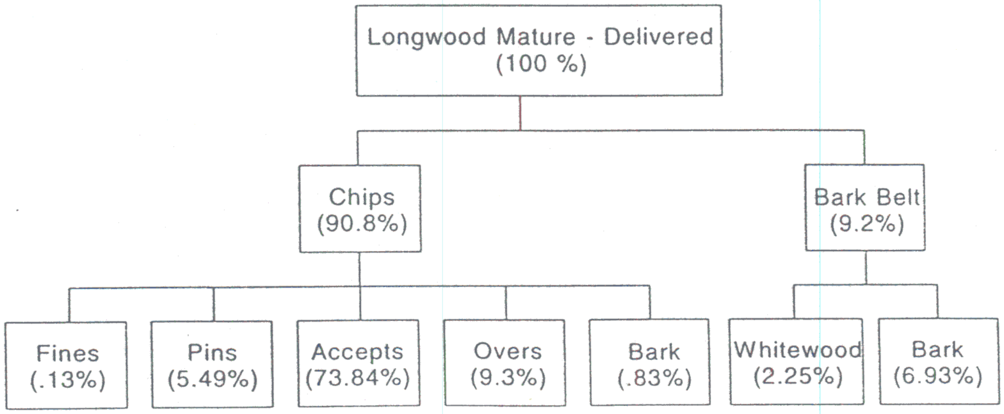


Figure 1. Utilization of tree-length wood processed through tree-length drum debarker.

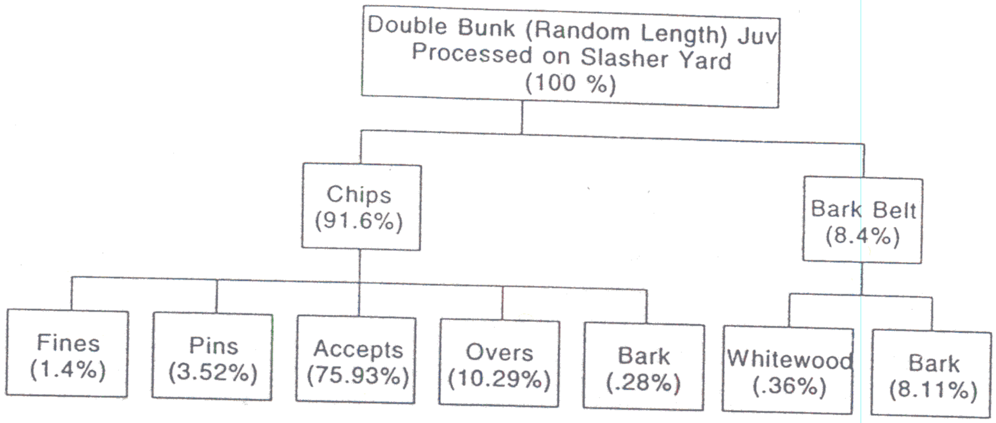


Figure 2. Utilization of cut-to-length wood slashed to 1.5 m lengths and processed through shortwood drum debarker.

The wood flow and utilization of various harvesting products are shown in Figures 1—4. The wood flow recovery for the tree-length and cut-to-length are for the roundwood delivered to the mill, drum debarked, chipped and screened for merchantable chips to the digester. The wood flow for the chips produced in-woods with the flail/chipper includes the whole tree converted to chips and then screened for merchantable chips to the digester.

In this analysis, recovery at the forest was assumed the same for the tree-length and CTL options. Only 71.3—77.0 percent of the total standing biomass was delivered to the mill. Almost 91 percent of the delivered tree-length wood resulted in chips (Figure 1). Over 9.2 percent became residue, or bark by-products that are usually used in the boilers. As more satellite chip mills have been established, this by-product has become more of a waste problem than a readily available fuel source. When the CTL wood was slashed and processed through the shortwood drum, almost 92 percent of the roundwood was converted into chips (Figure 2) and the rest was bark residue. When the CTL wood was processed through the longwood drum without slashing, there was a lot of breakage that resulted in more bark residue. Over 12 percent went into the bark pile for this option (Figure 3). All three alternatives had some additional residues generated after screening.

Figure 4 illustrates the wood flow and recovery for the flail/chip process. Over 60 percent of the whole tree that goes through the flail goes to the chip van and 39.4 percent is left on site. Some of the residues are spread across the site, but much is piled at the deck as a result of the flail processing. Sometimes this material is hogged and hauled to the mill for energywood. When screened at the mill, recovery of acceptable chips is 82.1 percent and only a small percent of residues are generated at the mill.

Mills handle the overs in many ways and for this simplistic analysis, overs were added to the accepts. These recovery percentages for the three harvesting systems (cut-to-length had two processing options) were used to convert the stand data into clean, acceptable chips to the digester (Table 5) and to determine points along the wood flow where residues are generated. These recovery figures should be used with caution since they are based on a small sampling. Also, the problem of breakage associated with processing CTL wood in a longwood drum may only be associated with the test mill.

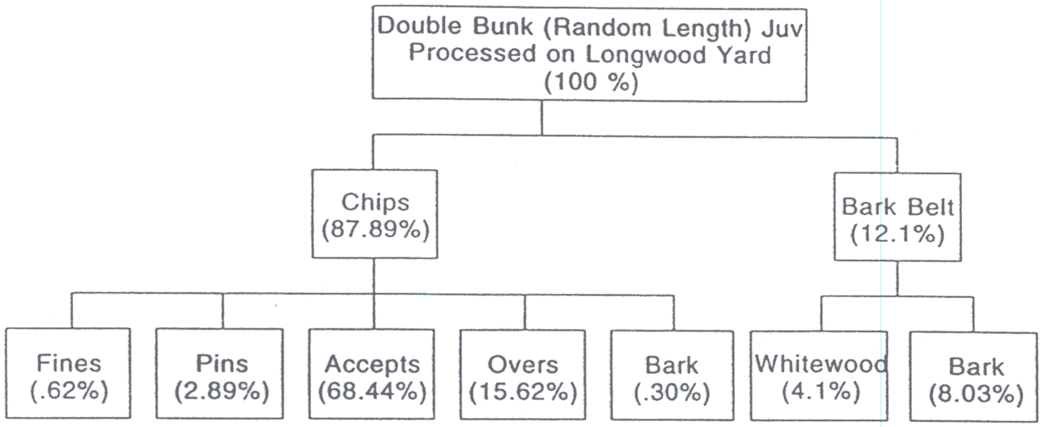


Figure 3. Utilization of cut-to-length wood processed through tree-length drum debarker.

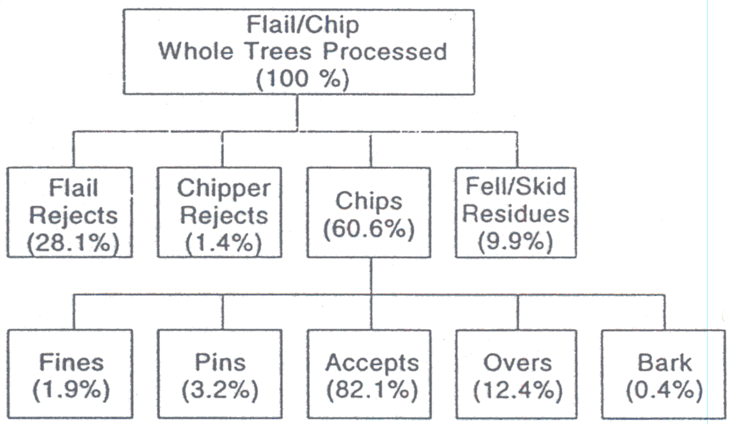


Figure 4. Utilization of whole trees processed through flail delimber/debarker and chipper.

In the early thinning, 13.9 tonnes/ha of residues were left on the site when roundwood was delivered to the mill. This analysis did not consider the unmerchantable pine or any hardwood on site. There could have been even more potential biomass left as a function of the thinning operations. This could also be true of the older thinnings which left 15.7 tonnes/ha on the site for tree-length and CTL systems. The flail system left an additional 5.2 tonnes/ha for the early thinning and 6.1 tonnes/ha for the older thinning. At the mill, 5.6—6.7 tonnes/ha, dependent on stand and wood type, were generated as bark residue. Only a small amount was generated by the screening process of the flail chips.

The clearcuts produced much more residual biomass for all the harvest systems. When hauling roundwood to the mill, it produced almost 22.4 tonnes/ha as drum debarker residues. These residues usually go to the boiler. The flail produced 70.4 tonnes/ha at the forest site.

The flail/chip system generates the most residues collected in one point. However, the added cost of processing and hauling lessen the use of this biomass in energy production. The roundwood systems generated usable residue at a mill facility and are readily available for energy production.

Table 5. Recovery of representative stands.

	Thinning, 13-15 yrs				Thinning, 16-18 yrs				Clearcut, 23 yrs			
	CTL		TL	FC	CTL		TL	FC	CTL		TL	FC
	1.5-m	NS			1.5-m	NS			1.5-m	NS		
	Tonnes/ha											
Residues at wood	13.9	13.9	13.9	19.1	15.7	15.7	15.7	21.7	41.0	41.0	41.0	70.4
Delivered Rdwd/Chips	34.5	34.5	34.5	29.4	39.7	39.7	39.7	33.6	137.6	137.6	137.6	108.3
Residual at mill	5.6	5.6	5.8	1.6	6.3	6.3	6.7	1.8	22.0	23.3	32.3	6.1
Merchant-able chips	28.9	28.9	27.8	27.8	33.4	33.4	33.0	31.8	115.7	114.3	105.4	102.2

Note: CTL is cut-to-length; TL is tree-length; FC is flail/chipper; Rdwd is roundwood. NS means that the CTL was not slashed and was processed in tree-length drum.

References

DOE/EIA. 1997. Renewable Energy Annual 1996. U.S. Department of Energy/Energy Information Administration. Report DOE/EIA-0603(96), July, 1997. Washington, DC.

DOE/EIA. 1997. Renewable Energy Annual 1997. U.S. Department of Energy/Energy Information Administration. Volume I, October, 1997, Washington, DC.

Flowers, R.K., W.F. Watson, B.K. Wharton, M.L. Belli & B.J. Stokes. 1992. Utilization and yield of chips from loblolly pine in central Arkansas. In: Proceedings of the 1992 TAPPI Pulping Conference; 1992 November 1-5; Boston, MA. Atlanta, GA: TAPPI Press. Book 2: 467-471.

Stokes, B.J. & W.F. Watson. 1988. Flail processing: an emerging technology for the South. Paper No. 88-7527, American Society of Agricultural Engineers, St. Joseph, MI. 18 p.

Stokes, B.J. & W.F. Watson. 1996. Plantation thinning systems in the Southern United States. In: Mitchell, Paul; Stevens, Eric; Kofman, Pieter D. (eds). Problems and prospects for managing cost effective early thinnings. A report from the Concerted action "Cost Effective Early Thinnings" AIR2-CT93-1538. Danish Forest and Landscape Research Institute, Horsholm, Denmark. 107-121.

Watson, B. & B. Stokes. 1994. Cost and utilization of above ground biomass in thinning systems. In: Proceedings of the COFE meeting on Advanced Technology in Forest Operations: Applied Technology in Action; 1994 July 24-29; Portland, OR. Corvallis, OR: Oregon State University: 192-201.

Watson, W.F., B.J. Stokes, L.N. Flanders, T.J. Straka, M.R. Dubois & G.J. Hottinger. 1992. Cost comparison at the woodyard chip pile of clean woodland chips and chips produced in the woodyard from roundwood. In: Proceedings of the 1991 TAPPI Pulping Conference; 1991 November 3-7; Orlando, FL. Atlanta, GA: TAPPI Press: 183-189.

IEA Bioenergy

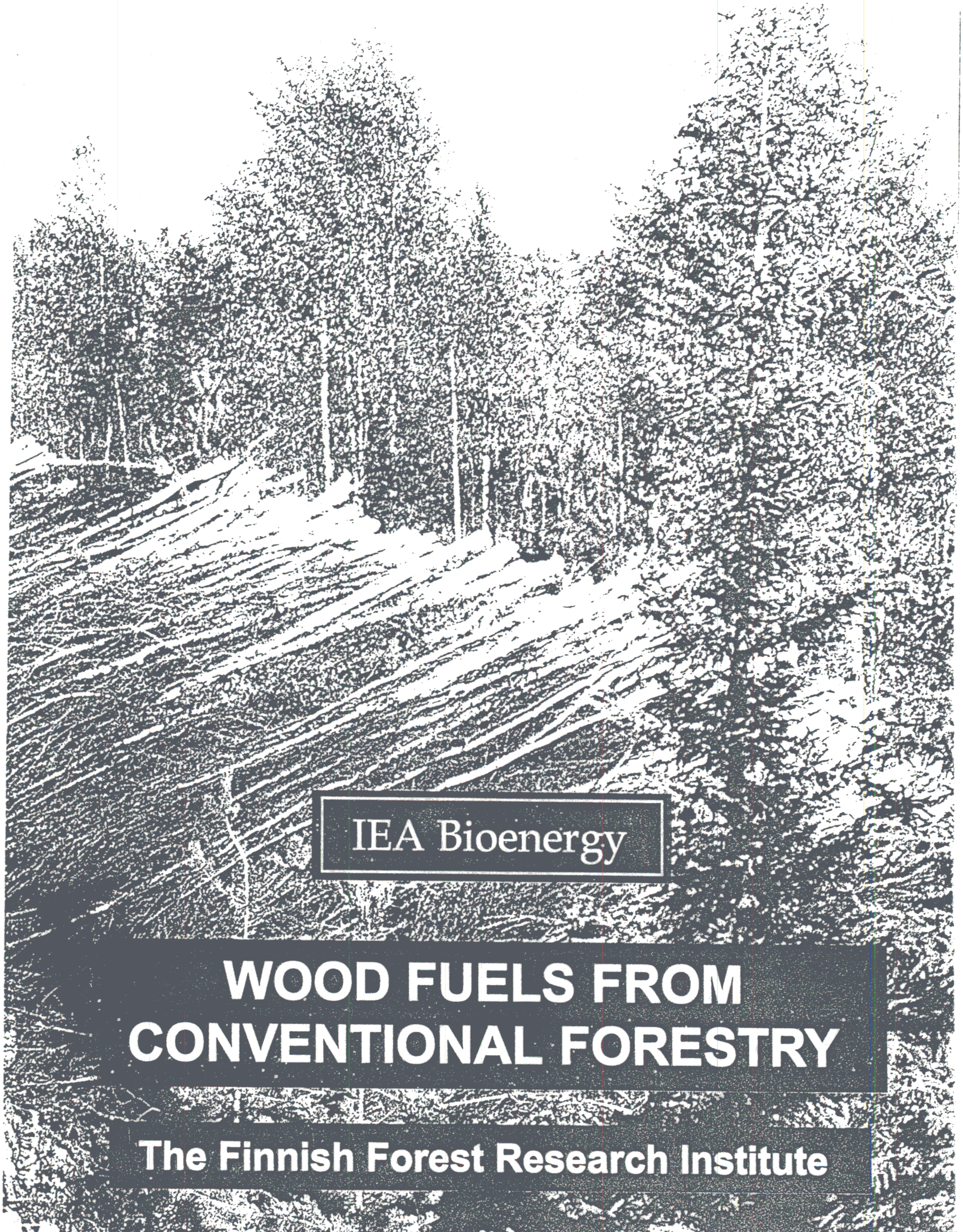
WOOD FUELS FROM CONVENTIONAL FORESTRY

Proceedings of the third annual workshop
of Activity 1.2 (Harvesting) / Task XII / IEA Bioenergy
in Jasper, Alberta
October 18, 1997

Edited by
Pentti Hakkila, Maija Heino and Essi Puranen

The Finnish Forest Research Institute
Vantaa Research Centre

Metsäntutkimuslaitoksen tiedonantoja 680
The Finnish Forest Research Institute. Research Papers 680
Vantaa 1998



IEA Bioenergy

WOOD FUELS FROM CONVENTIONAL FORESTRY

The Finnish Forest Research Institute

Hakkila, P., Heino, M. and Puranen, E. (eds.). 1998. Wood fuels from conventional forestry. Metsäntutkimuslaitoksen tiedonantoja 680. The Finnish Forest Research Institute. Research Papers 680. 122 p. ISBN 951-40-1618-1, ISSN 0358-4283

The publication is the Proceedings of the third annual workshop of Activity 1.2 (Harvesting)/Task XII/IEA Bioenergy in Jasper Alberta in October 18, 1997. It is composed of eleven papers dealing with various aspects of the production of wood fuels from conventional forestry. An overview is given of the Alberta forest sector, potential applications of bioenergy in Canada's remote communities, and timber procurement systems of the southeastern United States. Several articles discuss new techniques and the state of the art of wood fuel harvesting, and characteristics and standards of wood chips. An evaluation report of the Activity is also presented. The evaluation report describes the history of harvesting related cooperation within IEA Bioenergy and the main developments during past ten years, and discusses wood fuel harvesting issues and the advantages and disadvantages of IEA Bioenergy cooperation.

Key words: IEA, bioenergy, fuelwood, harvesting, conventional forestry

Publisher: IEA Bioenergy / Finnish Forest Research Institute

Correspondence: Pentti Hakkila: The Finnish Forest Research Institute, Vantaa Research Centre, P.O. Box 18, FIN-01301 Vantaa, Finland. Tel: +358 9 857 051, Fax: +358 9 8570 5361

Distribution: The Finnish Forest Research Institute, Unioninkatu 40 A, FIN-00170 Helsinki, Finland. Phone: +358 9 857 051, Fax: +358 9 625 308

ISBN 951-40-1618-1
ISSN 0358-4283

Gummerus Kirjapaino Oy
Jyväskylä 1998